Title

Lighted Status Indicator Corresponding to the Positions of Circuit Breaker, Switch or Fuse

This application claims priority on provisional application Serial No. 60/172,187, filed December 17, 1999.

Technical Field

This invention relates, in general, to circuit breakers, switches, and fuses used in electronic circuits, and in particular, to status indicators and momentary test switches for circuit breakers.

Background Art

An evaluation of patents in this field (status indicators for circuit breakers, switches, or fuses) reveals that existing technology is significantly different from, and inferior to, that claimed by the applicant.

Relevant US patents examined were: 4,056,816 (Guim), 4,652,867 (Masot), 4,672,351 (Cheng), 5,233,330 (Hase), 5,343,192 (Yenisey), 5,353,014 (Carroll et al.), 5,812,352 (Rokita et al.), and 5,920,451 (Fasano et al.)

Evaluation of relevant patents in this field has revealed that:

- All previously issued patents describe a circuit that uses a single indicator to indicate *either* the "OPEN/TRIPPED" or the "CLOSED" position, or uses multiple indicators (usually separate LEDs) to display multiple possible conditions. Existing technology does not allow a single lighted display element to indicate status for *all* possible breaker, switch, or fuse conditions.

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- Some of the issued patents require that a parallel circuit or set of contacts be implemented together with the circuit breaker, switch, or fuse in order to activate the indicator light.

- Some patents in this area require active elements to monitor the status of the circuit breaker or switch. Such circuits are less reliable and more expensive than circuits that use only passive elements.

- Some of the previously issued patents apply only to AC or DC powered systems. Those used in DC systems may or may not function with both polarities.

- None of the technologies in existing patents incorporates a momentary test switch circuit that allows all circuit breaker, switch, or fuse status indicators to be simultaneously tested, using a single bi-color lighted status indicator per breaker/switch.

- Finally, all circuits described in related patents are designed to be used with specific supply voltages and will not function correctly outside that supply range.

The invention claimed by the applicants addresses all these problems. It describes a circuit breaker, switch, or fuse status indicator that incorporates a lighted visual display *with a multi-color light source*, eliminating the need for multiple light sources (such as LEDs or back-lit LCDs) to display the various possible positions of a breaker.

A circuit that uses a single multi-color light source for status display is superior to existing circuits with multiple light sources. Using of multiple light sources introduces extra expense and complexity to status indicator circuitry and can unnecessarily consume scarce room on the front of circuit breaker (or a panel adjacent to the circuit breaker).

The circuit breaker status indicator uses an inexpensive, passive electronic circuit that takes advantage of the status contact switch of the circuit breaker to change the color of

that light source, depending upon the status (or position) of the circuit breaker. This circuit can also easily be configured to support a wide range of AC and DC (both positive and negative) voltages, and to include a momentary test switch circuit.

Summary

A lighted status indicator for a contact (circuit breaker, switch or fuse) with a distinctive color associated with each position of the circuit breaker. The lighted status indicator is composed of a multi-color light source (usually an LED) together with an electronic circuit that changes the color of that light source, depending upon the status (or position) of the circuit breaker, switch, or fuse. This lighted status indicator features a number of innovations, including:

- Use of simple, non-active, and inexpensive electronic parts,
- Use of a single, bi-color light LED to indicate the "ON" and "OFF" conditions of a two-position circuit breaker or switch with two distinct colors (example: red and green), and
- Use of a single bi-color LED to indicate status in a circuit breaker with a mid-position feature (on/off/tripped–3 positions in all). This allows these three possible status conditions (positions) to be represented by two different colors in the "ON" and the "TRIPPED" positions, and by the LED being off in the manually set "OFF" condition. (A three-color light source could also be used with this technology, allowing the "ON," "TRIPPED," and "OFF" states to all be represented by a unique color.)

This technology also offers heretofore-unseen flexibility of implementation. The lighted status indicator may be:

- Used with AC, or DC (positive or negative ground) power supplies,
- Used in a wide supply voltage range,
- Either external to the circuit breaker (or switch or fuse) or incorporated into the circuit breaker (or switch or fuse),

- Used with, or without, an activated parallel circuit to a switch, circuit breaker or fuse, (double pole, double throw in the case of a switch, or auxiliary switch in the case of a circuit breaker),
- Used with, or without, a lower power dissipation option, and
- Used with, or without, a momentary test switch incorporated into the status indicator circuit, simulating a single circuit breaker, or a group of circuit breakers, being turned to a "TRIPPED" position, with an associated change in the color of the LED.

Brief Description of the Drawings

FIG. **1** is a circuit diagram of the Lighted Status Indicator circuit, where the switch is placed on the positive line, before line reaching the load, for a negative ground DC system.

FIG. **2** is the same as FIG. **1**, except that the circuit now includes current-limiting diodes.

FIG. **3** is the same as FIG. **1**, except that the circuit has been altered to work with an AC power supply.

FIG. **4** is the same as FIG. **1**, except that the circuit incorporates both the current-limiting diodes and AC power supply support.

FIG. **5** is a circuit diagram of the Lighted Status Indicator circuit, where the switch is placed on the negative line, before line reaching the load, for a positive ground DC system.

FIG. **6** is the same as FIG. **5**, except that the circuit now includes current-limiting diodes.

FIG. **7** is the same as FIG. **5**, except that the circuit has been altered to work with an AC power supply.

FIG. **8** is the same as FIG. **5**, except that the circuit incorporates both the current-limiting diodes and AC power supply support.

FIG. **9** is a circuit diagram of the Lighted Status Indicator circuit, where the circuit supports a lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, for a positive ground DC system.

FIG. **10** is the same as FIG. **9**, except that the circuit now includes current-limiting diodes.

FIG. **11** is the same as FIG. **9**, except that the circuit has been altered to work with an AC power supply.

FIG. **12** is the same as FIG. **9**, except that the circuit incorporates both the current-limiting diodes and AC power supply support.

FIG. **13** is a circuit diagram of the Lighted Status Indicator circuit, where the circuit supports a lighted position/status indicator for a mid-trip circuit breaker, with a built-in auxiliary switch. This circuit uses a bi-color LED, with the circuit breaker located between the positive side of power supply and load, and is designed for a negative ground DC system.

FIG. **14** is the same as FIG. **13**, except that the circuit now incorporates current limiting diodes. This circuit is designed for a negative ground DC system.

FIG. **15** is the same as FIG. **13**, except that the circuit has been altered to also work with an AC power supply.

FIG. **16** is the same as FIG. **13**, except that the circuit incorporates both the current-limiting diodes and AC power supply support.

FIG. **17** is a circuit diagram of the Lighted Status Indicator circuit where the circuit supports a lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, for a positive ground DC system. This circuit represents a lower power dissipation option than that shown in FIG. **9**.

FIG. **18** is the same as FIG. **17**, except that the circuit now includes a current-limiting diode.

FIG. **19** is the same as FIG. **17**, except that the circuit has been altered to also work with an AC power supply.

FIG. **20** is the same as FIG. **17**, except that the circuit incorporates both the current-limiting diode and AC power supply support.

FIG. **21** is a circuit diagram of the of the Lighted Status Indicator circuit where the circuit breaker is located between the positive side of power supply and load, for a negative ground DC system, that incorporates the lower power dissipation option.

FIG. **22** is the same as FIG. **21**, except that the circuit now includes a current-limiting diode.

FIG. **23** is the same as FIG. **21**, except that the circuit has been altered to also work with an AC power supply.

FIG. **24** is the same as FIG. **21**, except that this version of the circuit incorporates both the current-limiting diode and AC power supply support.

FIG. **25** is a circuit diagram of the Lighted Status Indicator circuit where the circuit supports the lighted position/status indicator as shown in FIG. **9**, and incorporates a circuit alarm test feature.

FIG. **26** is a circuit diagram of the Lighted Status Indicator circuit where the circuit supports an alarm test circuit for several lighted position/status indicator circuit breakers.

FIG. **27** is a circuit diagram for a one rack unit power distribution unit (PDU) using mid-trip circuit breaker, with lighted status/position indicators and an alarm test circuit, for a positive ground DC system.

FIG. **28** illustrates the one rack unit PDU, using mid-trip circuit breaker, lighted status/position indicators, and an alarm test circuit, diagrammed in FIG. **27**.

FIG. **29** shows a compact circuit breaker incorporating a mid-trip switch, a lighted status indicator for the ON/OFF/TRIPPED positions, auxiliary "normally open"/"normally closed" contact points for remote monitoring of the circuit breaker system, and an alarm circuit momentary test switch, for AC or positive or negative ground DC systems.

FIG. **30** is a circuit diagram for the compact circuit breaker shown in FIG. **29**, with a lighted status indicator for ON/OFF/TRIPPED positions, for a positive ground DC system.

FIG. **31** shows how the circuit diagram in FIG. **30** could be modified to support a DPDT (Dual Poll, Dual Throw) momentary test switch

FIG. **32** shows the FIG. **30** circuit with the addition of two current-limiting diodes.

FIG. **33** shows the FIG. **30** circuit reconfigured to support an AC power supply.

FIG. **34** shows the FIG. **30** circuit reconfigured to incorporate both current-limiting diodes and AC power supply support.

FIG. **35** is a circuit diagram of the Lighted Status Indicator circuit for a mid-trip circuit breaker, using a SPDT as a main contact and an auxiliary switch SPDT for tripped status indication, for a positive ground DC system.

FIG. **36** is the same as FIG. **35**, except that the circuit has been altered to work with a negative ground DC system.

FIG. **37** is the same as FIG. **35**, except that the circuit has been altered to work with a positive ground DC or an AC power system.

FIG. **38** is the same as FIG. **36**, except that the circuit has been altered to work with a negative ground DC or an AC system.

FIG. **39** is a circuit diagram of the Lighted Status Indicator circuit for a mid-trip circuit breaker using a SPST as a main contact and an auxiliary switch SPST for tripped status indication for a negative ground DC or an AC system.

FIG. **40** is the same as FIG. **39**, except that the circuit has been altered to work with a positive ground DC or an AC power system.

FIG. **41** is a circuit diagram of the Lighted Status Indicator circuit for a mid-trip circuit breaker using a SPST as a main contact and an auxiliary switch SPDT (or a SPST) for tripped status indication with alarm test push button switch, for a positive ground DC or an AC system.

FIG. **42** is circuit diagram of the Lighted Status Indicator circuit for a mid-trip circuit breaker using a SPST as a main contact and an auxiliary switch (SPDT) for tripped status with alarm test push button switch, for a positive ground DC or an AC system.

FIG. **42** is the same as FIG. **41** except for alterations necessary to support multiple circuit breakers are connected to the same push-button test switch.

FIG. **43** is the same as FIG. **42**, except that the circuit has been altered to work with a negative ground DC or an AC system.

FIG. **44** is circuit diagram of the Lighted Status Indicator circuit for a fuse with alarm circuit and alarm test switch, for a positive ground DC (or AC) system.

FIG. **45** illustrates side and front views of the L-Module—a compact breaker-mounted module display of individual breaker status.

FIG. **46** illustrates a side view of a series of L-Modules daisy-chained together, and monitored by an Alarm/Status Module.

FIG. **47** is a circuit diagram of the Alarm/Status Module, together with a series of daisy-chained L-Modules that it monitors.

FIG. **48** is a circuit diagram of a variation of the Alarm/Status Module designed for use in a dual power system.

FIG. **49** illustrates side and front views of the Direct Status Output L-Module—a compact breaker-mounted module display of individual breaker status, designed to support independent monitoring of individual circuit breakers.

FIG. **50** is a circuit diagram of the Direct Status Output L-Module.

FIG. **51** is a circuit diagram of an L-Module designed for a switch, fuse, or circuit breaker with no auxiliary switch, or circuit breakers with no mid-trip capability.

Detailed Description of the Invention

Item 1: Switch placed on the positive line, before line reaching the load, negative ground system.

Description:

The circuit in FIG. **1** consists of three resistors—**4**, **2**, and **3**, a diode—**6**, and a bi-color LED **5**. The circuit is connected across the circuit breaker/switch/fuse **1**, with resistor **2** connected to point C **10**, and diode **6** connected to point D **11**. The common connection point of resistors **4** and **3** is connected to the negative side of the DC supply at point F **12**.

Elements of the FIG. 1 Circuit:

1–Switch	**5**–Bi-Color LED	**9**–Point "B"
2–Resistor	**6**–Diode	**10**–Point "C"
3–Resistor	**7**–Load	**11**–Point "D"
4–Resistor	**8**–Point "A"	**12**–Point "F"

Function:

When the circuit breaker/switch/fuse **1** is Closed, current will flow through the diode **6**, from point D **11** to point B **9**, through the LED **5** from point B **9** to point A **8**, and then through the resistor **3** from point A **8** to point F **12**. Current flowing in this direction will cause the LED **5** to glow Green. (In FIG. **1**—as in the rest of this document—Green is used as an example of an indicator color; other color LEDs or light sources could be substituted with no significant changes to the circuits described.)

A second path of current flows from point D **11** to point B **9** (passing through the diode **6**), and then from point B **9** to point F **12** (passing through the resistor **4**). A small amount of current will also run from point C **10** to point A **8** (passing through resistor **2**), and then on to point F **12** (via the resistor **3**). This current is equal to the voltage drop across points D **11** and A **8** (equal to 2 diode drops), divided by the value of the resistor **2**.

The values of resistors **4**, **2**, and **3** control the amount of the current flowing from point B **9** to point A **8**, with a minimum value of 10 mA and a maximum value of 20 mA (typical functional current range for an LED).

When the circuit breaker/switch/fuse **1** is OPEN/TRIPPED, current will flow from point C **10** to point A **8**, and then divide into two parts. A portion of that current flows from point A **8** to point B **9** (passing through the LED **5**), and then from point B **9** to point F **12**, (passing though the resistor **4**). This current stream causes the bi-color LED **5** to glow RED. A second portion of the current will flow from point A **8** to point F **12** (passing through the resistor **3**). The diode **6** will block any current flow from point B **9** to point D **11**. (In FIG. **1**—as in the rest of this document—RED is used as an example of an indicator color; other color LEDs or light sources could be substituted with no significant changes to the circuits described.)

The values of resistors **4**, **2**, and **3** control the amount of the current flowing through the LED **5** in the direction of point A **8** to point B **9**. In this case, the minimum current flow will also be 10 mA and the maximum will be 20 mA, depending on the desired light intensity and amount of power dissipation.

Item 2: Switch placed on the positive line, before line reaching the load, with current-limiting diodes, for a negative ground DC system.

Description:

FIG. **2** is identical to the FIG. **1** circuit, except that two current-limiting diodes (**15** and **18**) have been added in series with the resistors, **17** and **16**. These diodes act to limit the current through the LED **19** to a maximum allowed by the diode specification (typically 10 to 15 mA).

Elements of the FIG. 2 Circuit:

13–Switch	**18**–Current-limiting Diode	**23**–Point "B"
14–Resistor	**19**–Bi-Color LED	**24**–Point "C"
15–Current-limiting Diode	**20**–Diode	**25**–Point "D"
16–Resistor	**21**–Load	**26**–Point "F"
17–Resistor	**22**–Point "A"	

Function:

Adding these current-limiting diodes allows the circuit to be used with a wide range of supply voltages. Current through the LED **19** will not exceed the regulating current of the diodes **15** or **18**. Diode **15** regulates the LED current in the direction of point B **23** to point A **22** (LED is GREEN; breaker/switch/fuse is CLOSED), while diode **18** regulates the LED current in the direction of point A **22** to point B **23** (LED is RED; breaker/switch/fuse is OPEN/TRIPPED).

The maximum DC supply voltage tolerated by the circuit will depend on the maximum voltage allowed across the diode **15** or **18** (typically 50 VDC). It will be equal to the maximum voltage allowed across diode **15** (or **18**) plus the voltage across the resistor **16** (or **17**). Since the current through these resistors (**16** or **17**) is limited by the diodes **15** and **18**, the voltages will also be limited

The circuit in FIG. **2** can be easily modified for use at a higher DC supply voltages. To support increased voltages, it is necessary to add one or more additional current-limiting diodes in series with diode **15** and **18**. Typically, each extra current-limiting diode added, in series, with the resistors **17** and **16** will increase the DC supply voltage limit by 50 VDC. This circuit will also function with just the two current-limiting diodes, and without the resistors, **17** and **16**.

Item 3: Switch placed on the line, before line reaching the load, for use with AC power supply.

Description:

Using the circuit shown in FIG. **1** as a base, a diode **28** (similar to the diode **33**) is added on the path of junction point C **37** to resistor **29**, resulting in the circuit in FIG. **3**.

Elements of the FIG. 3 Circuit:

27–Switch	**32**–Bi-Color LED	**37**–Point "C"
28–Diode	**33**–Diode	**38**–Point "D"
29–Resistor	**34**–Load	**39**–Point "F"
30–Resistor	**35**–Point "A"	
31–Resistor	**36**–Point "B"	

Function:

Adding the extra diode **28** allows the circuit to be used with an AC power supply, as well as with a negative ground DC power supply. The functionality of the circuit remains the same, except that the current will now flow in half cycles in either direction through the LED **32,** depending on the position of the on/off switch.

Item 4: Switch placed on the line, before line reaching the load, with current-limiting diodes, for use with AC power supply.

Description:

Adding current-limiting diodes, **43** and **46**, to the circuit in FIG. **3** allows a wider AC supply voltage range to be tolerated. FIG. **4** shows such a configuration.

Elements of the FIG. 4 Circuit:

40–Switch	**45**–Resistor	**50**–Point "A"
41–Diode	**46**–Current-Limiting Diode	**51**–Point "B""
42–Resistor	**47**–Bi-Color LED	**52**–Point "C"
43–Current-Limiting Diode	**48**–Diode	**53**–Point "D"
44–Resistor	**49**–Load	**54**–Point "F"

Function:

The addition of the current-limiting diodes, in series, with the diodes **43** and **46** increases the circuit's AC supply voltage limit, while not allowing the current through the LED **47** to exceed that LED's limits. The maximum voltage tolerated corresponds to the peak voltage of the positive half cycle of the AC power supply. This circuit could also be used with just the two current limiting diodes, **43** and **46**, and without the two resistors, **44** and **45**.

Item 5: Switch placed on the negative line, before line reaching the load, positive ground DC system.

Description:

The circuit in FIG. **5** consists of three resistors (**57**, **59**, and **58**), a diode (**61**), and a bi-color LED **60**. The circuit is connected across the circuit breaker/switch/fuse **55**, with resistor **59** connected to point F **66**, and diode **61** connected between points B **63** and D **65**. The common connection point of resistors **57** and **58** is connected to the positive side of the DC supply at point C **64**.

Elements of the FIG. 5 Circuit:

55–Switch	**59**–Resistor	**63**–Point "B"
56–Load	**60**–Bi-Color LED	**64**–Point "C"
57–Resistor	**61**–Diode	**65**–Point "D"
58–Resistor	**62**–Point "A"	**66**–Point "F"

Function:

When the circuit breaker/switch/fuse **55** is CLOSED, a current will flow through the resistor **58**, the LED **60**, the diode **61**, and through the switch **55** to point F **66**. This current stream causes the LED **60** to glow GREEN.

A second path of current will run from point C **64** to point F **66** (passing through the resistor **57**, the diode **61**, and the switch **55**). A small amount of current will also run from point A **62** to point F **66** (passing through resistor **59**). This current is equal to the voltage drop across the LED **60** and the diode **61** (equal to 2 diode drops), divided by the value of the resistor **59**.

The values of resistors **57**, **59**, and **58** will control the amount of the current flowing from point A **62** to point B **63**, with a minimum value of 10 mA and a maximum value of 20 mA (typical functional current range for an LED).

When the circuit breaker/switch/fuse is OPEN/TRIPPED, current will flow from point C **64** to point B **63**, and then from point B **63** to point A **62** (passing though the LED **60**), and then from point A **62** to point F **66**. This current will cause the bi-color LED **60** to glow RED. A second path of current will flow from point C **64** to point A **62** (passing though the resistor **58**, and then through the resistor **59**) to point F **66**.

The values of resistors **57**, **59**, and **58** will control the amount of the current flowing through the LED **60** in the direction of point B **63** to point A **62**. The minimum current will be 10 mA and the maximum will be 20 mA, depending on the desired light intensity and amount of power dissipation.

Item 6: Switch placed on the negative line, before line reaching the load, with current-limiting diodes, for a positive ground DC system.

Description:

The circuit in FIG. **6** is identical to that shown in FIG. **5**, except that two current-limiting diodes, **71** and **69**, have been added in series with the resistors, **70** and **72**.

Elements of the FIG. 6 Circuit:

67–Switch
68–Load
69–Current-Limiting Diode
70–Resistor
71–Current-Limiting Diode
72–Resistor
73–Resistor
74–Bi-Color LED
75–Diode
76–Point "A"
77–Point "B"
78–Point "C"
79–Point "D"
80–Point "F"

Function:

As previously explained under Item 2, the addition of current-limiting diodes (**69** and **71**) regulates the maximum current flow, and increases the range of DC supply voltages that the circuit will tolerate.

The circuit in FIG. **6** could be easily modified to support higher DC supply voltages. Placing additional current-limiting diodes, in series with the diodes **71** and **69**, will further increase the DC supply voltage limit. This circuit could also be used with just the two current-limiting diodes, and without the two resistors, **70** and **72**.

Item 7: Switch placed on the line, before line reaching the load, for use with AC power supply.

Description:

FIG. **7** shows the addition a diode **88** (similar to the diode **87**) on the path of junction point F **93** to the resistor **85**, to the circuit diagrammed in FIG. **5**

Elements of the FIG. 7 Circuit:

81–Switch	**86**–Bi-Color LED	**91**–Point "C"
82–Load	**87**–Diode	**92**–Point "D"
83–Resistor	**88**–Diode	**93**–Point "F"
84–Resistor	**89**–Point "A"	
85–Resistor	**90**–Point "B"	

Function:

By adding this additional diode **88**, the FIG. **7** circuit can be used with either an AC power supply or positive ground DC power supply (as described under Item 3).

Item 8: Switch placed on the line, before line reaching the load, with current-limiting diodes, for use with AC power supply

Description:

Adding current-limiting diodes, **98** and **96**, to the circuit shown in FIG. **7** allows a wider AC supply voltage range to be tolerated. FIG. **8** shows such a configuration.

Elements of the FIG. 8 Circuit:

94–Switch	**99**–Resistor	**104**–Point "A"
95–Load	**100**–Resistor	**105**–Point "B"
96–Current-Limiting Diode	**101**–Bi-Color LED	**106**–Point "C"
97–Resistor	**102**–Diode	**107**–Point "D"
98–Current-Limiting Diode	**103**–Diode	**108**–Point "F"

Function:

The addition of more current-limiting diodes, in series, with the diodes, **98** and **96**, increases the AC supply voltage limit (as explained under Item 4). This circuit could also be used with just the two current-limiting diodes, **98** and **96**, and without the resistors, **97** and **99**.

Item 9: Lighted position/status indicator for a mid-trip circuit breaker with built-in auxiliary switch, using a bi-color LED, positive ground system.

Description:

A mid-trip circuit breaker is a switch that automatically opens up when the current passing through the switch contacts exceeds a pre-set value. Included in the circuit breaker structure is a separate auxiliary switch—a STDT (single pole, double throw) switch. This auxiliary switch only changes status when the circuit breaker is in a TRIPPED state. Manually opening or closing the circuit breaker does not change the status of the auxiliary switch. Depending upon the application, this auxiliary switch is either used to remotely monitor the status of the circuit breaker, or to remotely activate other devices.

The circuit in FIG. **9** contains two resistors (**112** and **115**), a diode (**111**), and a bi-color LED **113** that indicates the status of the circuit breaker. This LED **113** either glows GREEN or RED, or is OFF, depending upon the status of the circuit breaker.

The diode **111** and the resistor **115** are connected, respectively, to points D **116** and F **118** of the circuit breaker. Point F **118** is also connected to the negative point of the DC power supply, while point D **116** is connected to the negative input of the load **110**. One side of the LED **113** is connected to resistor **112** and to the "normally open" side of the auxiliary switch **114**. The other side of the LED **113** is connected to the resistor **115** and to the "normally closed" side of the auxiliary switch **114**. The center position of the auxiliary switch **114** is connected to the positive side of the power supply.

Elements of the FIG. 9 Circuit:

109–Circuit Breaker	**113**–Bi-Color LED	**117**–Point "E"
110–Load	**114**–Auxiliary Switch	**118**–Point "F""
111–Diode	**115**–Resistor	
112–Resistor	**116**–Point "D"	

Function:

Under normal conditions (when the circuit breaker is in the CLOSED state), a current flows from point E **117** (+VDC), through the "normally closed" contact of the auxiliary switch **114**, the LED **113**, the resistor **112**, the diode **111**, the circuit breaker **109**, point F **118**, and on to the negative of the power supply). This current will cause the bi-color LED **113** to glow GREEN. A second path of current will also run through the auxiliary switch **114** to point F **118** (passing through the resistor **115**).

When the circuit breaker **109** is manually turned to the OFF position, no current will flow through the LED **113**, and the LED **113** will be in OFF state. In this condition, current will still flow through the auxiliary switch **114** to point F **118** (passing through resistor **115**), and on to the negative side of the power supply. (In FIG. **9**—as in the rest of this document—the OFF state is used as an example of an indicator "color." A three-state LED, using any three colors—or any two colors and an OFF state—could be substituted with no significant changes to the circuits described.)

When the circuit breaker **109** is TRIPPED (in an over limit current condition), it will automatically open the circuit breaker main contact, and also activate the auxiliary switch **114**. When that happens, a current will flow from point E **117** (+VDC circuit ground) through the auxiliary switch **114** (from the "center" to "normally open" points) to point F **118** (passing through the LED **113**, and the resistor **115**). This current flow will cause the LED to turn RED, indicating an alarm condition.

The values selected for the resistors **112** and **115** depend on the desired light intensity for the LED **113** (for both GREEN and RED states), and power dissipation considerations.

Item 10: Lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, with current-limiting diodes, for a positive ground DC system.

Description:

FIG. **10** is identical to the FIG. **9** circuit, except that two current-limiting diodes (**123** and **126**) have been added in series with the resistors (**122** and **127**). These diodes restrict the current through the LED **124** to a maximum allowed by the diode specifications.

Elements of the FIG. 10 Circuit:

125–Auxiliary Switch	**129**–Point "E"	**121**–Diode
126–Current-Limiting Diode	**130**–Point "F"	**122**–Resistor
127–Resistor	**119**–Breaker	**123**–Current-Limiting Diode
128–Point "D"	**120**–Load	**124**–Bi-Color LED

Function:

Adding the current-limiting diodes will allow the circuit to be used with a wider DC supply voltage range. In this configuration, the current through the LED **124** can not exceed the regulating current of the diodes, **123** and **126**.

The circuit could also be used with just the two current-limiting diodes, **123** and **126**, and without the two resistors, **122** and **127**. Adding additional current-limiting diodes, in series, will further increase the DC supply voltage tolerated.

Item 11: Lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, for use with AC power supply.

Description:

In FIG. **11**, the circuit shown in FIG. **9** is modified by the addition of a diode **138** (similar to the diode CR **133**) on the path of junction point F **141** to resistor **137**.

Elements of the FIG. 11 Circuit:

131–Circuit Breaker	**135**–Bi-Color LED	**139**–Point "D"
132–Load	**136**–Auxiliary Switch	**140**–Point "E"
133–Diode	**137**–Resistor	**141**–Point "F"
134–Resistor	**138**–Diode	

Function:

Adding the diode **138** allows the circuit to be used with AC power supplies, as well as with DC power supplies (for positive ground systems). The functionality of the circuit remains the same, except that the current will now flow in half cycles in either direction through the LED **135**.

Item 12: Lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, with current-limiting diodes, for use with AC power supply.

Description:

By adding current-limiting diodes, **146** and **149**, to the circuit shown in FIG. **11**, a wider AC supply voltage range can be tolerated. FIG. **12** shows this configuration.

Elements of the FIG. 12 Circuit:

142–Circuit Breaker	**147**–Bi-Color LED	**152**–Point "D"
143–Load	**148**–Auxiliary Switch	**153**–Point "E"
144–Diode	**149**–Current-Limiting Diode	**154**–Point "F"
145–Resistor	**150**–Resistor	
146–Current-Limiting Diode	**151**–Diode	

Function:

The addition of more current-limiting diodes, in series, with the diodes, **146** and **149**, increases the AC supply voltage limit (as explained under Item 4).

This circuit could also be used with just the two current-limiting diodes, **146** and **149**, and without the resistors, **145** and **150**.

Item 13: Lighted position/status indicator for a mid-trip circuit breaker (located between the +VDC and the load) with built-in auxiliary switch, using a bi-color LED, negative ground system.

Description:

FIG. **13** illustrates how the status indicator circuit in FIG. **9** can be modified for use in a negative ground DC system.

Elements of the FIG. 13 Circuit:

155–Circuit Breaker	**159**–Resistor	**163**–Point "E"
156–Resistor	**160**–Diode	**164**–Point "F"
157–Auxiliary Switch	**161**–Load	
158–Bi-Color LED	**162**–Point "D"	

Function:

The circuit in FIG. **13** functions identically to the circuit in FIG. **9**, except that the current now flows from points D **162** and F **164** to point E **163** (passing through the components on each of the paths).

Item 14: Lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, circuit breaker located between the positive side of power supply and load, with current limiting diodes, for a negative ground DC system.

Description:

The circuit in FIG. **14** adds two current-limiting diodes, **170** and **167**, in series with the resistors, **171** and **166**, to the circuit diagrammed in FIG. **13**.

*Elements of the FIG. **14** Circuit:*

165–Circuit Breaker	**169**–Bi-Color LED	**173**–Load
166–Resistor	**170**–Current-Limiting Diode	**174**–Point "D"
167–Current-Limiting Diode	**171**–Resistor	**175**–Point "E"
168–Auxiliary Switch	**172**–Diode	**176**–Point "F"

Function:

The circuit in FIG. **14** functions identically to the circuit in FIG. **10**, except that the current now flows from points D **174** and F **176** to point E **175** (passing through the components on each of the paths).

Item 15: Lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, circuit breaker located between line and the load, for use with an AC power supply.

Description:

FIG. **15** adds a diode, **178** (similar to the diode **183**), between junction point F **187** and resistor **179**, to the circuit diagrammed in FIG. **13**.

*Elements of the FIG. **15** Circuit:*

177–Circuit Breaker	**181**–Bi-Color LED	**185**–Point "D"
178–Diode	**182**–Resistor	**186**–Point "E"
179–Resistor	**183**–Diode	**187**–Point "F"
180–Auxiliary Switch	**184**–Load	

Function:

The addition of this diode **178** allows the circuit to be used with AC power supplies, as well as with DC power supplies (negative ground systems). The functionality of the circuit remains the same, except that the current will now flow in half cycles in either direction through the LED **181**.

Item 16: Lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, circuit breaker located between line and the load, for use with an AC power supply, with current-limiting diodes.

Description:

By adding the current-limiting diodes, **194** and **191**, to the circuit shown on FIG. **15**, a wider AC supply voltage range will be obtained. FIG. **16** shows this configuration.

Elements of the FIG. 16 Circuit:

188–Circuit Breaker	**193**–Bi-Color LED	**198**–Point "D"
189–Diode	**194**–Current-Limiting Diode	**199**–Point "E"
190–Resistor	**195**–Resistor	**200**–Point "F"
191–Current-Limiting Diode	**196**–Diode	
192–Auxiliary Switch	**197**–Load	

Function:

The addition of more current-limiting diodes, in series, with the diodes, **194** and **191**, will increase the AC supply voltage limit (as explained under Item 4).

This circuit would also function with just the two current-limiting diodes, **194** and **191**, and without the resistors, **195** and **190**.

Item 17: Lighted position/status indicator for a mid-trip circuit breaker (located between the +VDC and the load) with built-in auxiliary switch, using a bi-color LED, for a positive ground system, lower power dissipation option.

Description:

The circuit in FIG. **17** contains three resistors (**207**, **208**, and **205**), a diode (**203**), and a bi-color LED **204** that indicates the status of the circuit breaker. The FIG. **17** circuit modifies the FIG. **9** circuit by moving the resistor **207** to a point between resistor **208** and the “normally closed” contact of the auxiliary switch **206**, and adding a third resistor **205** between the auxiliary switch **206** and point E **210** (+VDC supply). When using the FIG. **17** circuit in different applications, one side of the resistor **205** should always remain connected to the +VDC supply.

Elements of the FIG. 17 Circuit:

201–Circuit Breaker	**205**–Resistor	**209**–Point "D"
202–Load	**206**–Auxiliary Switch	**210**–Point "E"
203–Diode	**207**–Resistor	**211**–Point "F"
204–Bi-Color LED	**208**–Resistor	

Function:

This circuit dissipates less power than the circuit in FIG. **9**, for the same LED current. Lower power dissipation is implemented via the addition of the third resistor **205**. When the auxiliary switch **206** is in the “normally closed” position, the current flow is from point E **210** through the resistors **205** and **207**, through the LED **204**, the diode **203**, the circuit breaker **201**, and into the negative side of the power supply. Because the voltage drop across the LED **204** and the diode **203** is very low in comparison to the VDC, the current that flows through the resistor **208** to the negative side of the supply is minimal.

When the auxiliary switch **206** is in the “normally open” position, the current flow will be from point E **210**, through the resistor **205**, the LED **204**, and the resistor **208**, and into the negative side of the power supply.

If resistor values are chosen so that resistor **207** = resistor **208**, for an optimum current value, the current levels through the LED **204** at both conditions ("RED" and "GREEN") will be very close to each other. Current flow is less when the breaker is manually set to the OFF position (resistors **207**, **208**, and **205** are in series).

Item 18: Lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, lower power dissipation option, with a current-limiting diode, for a positive ground DC system.

Description:

The circuit in FIG. **18** adds a current-limiting diode **217**, in series, between the resistor **216** and point E **222**, to the circuit diagrammed in FIG. **17**.

Elements of the FIG. 18 Circuit:

212–Circuit Breaker	**216**–Resistor	**220**–Resistor
213–Load	**217**–Current-Limiting Diode	**221**–Point "D"
214–Diode	**218**–Auxiliary Switch	**222**–Point "E"
215–Bi-Color LED	**219**–Resistor	**223**–Point "F

Function:

Adding the diode **217** increases the DC power supply voltage tolerated, while keeping the current through the LED **215** within the desired limits.

The FIG. **18** circuit could also be modified to function without the resistor **216**, and with the resistor **219** replaced with a jumper wire (a zero ohm resistor).

Item 19: Lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, lower power dissipation option, for use with AC power supplies.

Description:

FIG. **19** modifies the circuit shown in FIG. **17**, adding an additional diode **232** (similar to the diode CR **226**) between point F **235** and the resistor **231**.

Elements of the FIG. 19 Circuit:

224–Circuit Breaker	**228**–Resistor	**232**–Diode
225–Load	**229**–Auxiliary Switch	**233**–Point "D"
226–Diode	**230**–Resistor	**234**–Point "E"
227–Bi-Color LED	**231**–Resistor	**235**–Point "F

Function:

Adding the extra diode **232** allows the circuit to be used with both AC and positive ground DC power supplies.

Item 20: Lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, with current-limiting diode, incorporating the lower power dissipation option, for use with AC power supplies.

Description:

The circuit shown in FIG. **20** is identical to that in FIG. **19**, except that a current-limiting diode **241** has been added between the resistor **240** and point E **247** (VAC Return).

Elements of the FIG. 20 Circuit:

236–Circuit Breaker	**241**–Current-Limiting Diode	**246**–Point "D"
237–Load	**242**–Auxiliary Switch	**247**–Point "E"
238–Diode	**243**–Resistor	**248**–Point "F"
239–Bi-Color LED	**244**–Resistor	
240–Resistor	**245**–Diode	

Function:

The addition of the current-limiting diode **241** allows a wider AC (or positive DC ground) supply voltage range to be tolerated.

Item 21: Lighted position/status indicator for a mid-trip circuit breaker with built-in auxiliary switch, using bi-color LED, with the circuit breaker located between the positive side of power supply and load, for a negative ground DC system, lower power dissipation option.

Description:

The circuit in FIG. **21** shows how the FIG. **17** circuit can be altered to accommodate a negative ground DC system. In the FIG. **21** circuit, the circuit breaker **249** is located between the positive side of power supply and load **256**. This version of the lighted status indicator circuit still supports a mid-trip circuit breaker with a built-in auxiliary switch **253**, and incorporates the lower power dissipation option.

Elements of the FIG. 21 Circuit:

249–Circuit Breaker	**253**–Auxiliary Switch	**257**–Point "D"
250–Resistor	**254**–Bi-Color LED	**258**–Point "E"
251–Resistor	**255**–Diode	**259**–Point "F"
252–Resistor	**256**–Load	

Function:

Except for the changes required to support a negative ground DC system, the circuit in FIG. **21** functions identically to the FIG. **17** circuit, dissipating less power than the standard lighted status indicator circuit (negative ground) for a mid-trip breaker (shown in FIG. **13**).

Item 22: Lighted position/status indicator for a mid-trip circuit breaker with built-in auxiliary switch, using bi-color LED, with the circuit breaker located between the positive side of power supply and load, for a negative ground DC system, with current-limiting diode, lower power dissipation option.

Description:

FIG. **22** adds a current-limiting diode **264**, in series, between the resistor **263** and point E **270**, to the circuit diagrammed in FIG. **21**.

Elements of the FIG. 22 Circuit:

260–Circuit Breaker	**264**–Current-Limiting Diode	**268**–Load
261–Resistor	**265**–Auxiliary Switch	**269**–Point "D"
262–Resistor	**266**–Bi-Color LED	**270**–Point "E"
263–Resistor	**267**–Diode	**271**–Point "F"

Function:

Adding the diode **264** increases the DC power supply voltage tolerated, while keeping the current through the LED **266** within the desired limits.

The FIG. **22** circuit could also be modified to function without the resistor **263**, and with the resistor **262** replaced with a jumper wire (a zero ohm resistor).

Item 23: Lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, with the circuit breaker located between the positive side of power supply and load, for an AC (or negative ground DC) system, lower power dissipation option.

Description:

FIG. **23** modifies the circuit shown in FIG. **21**, adding an additional diode **273** (similar to the diode CR **279**) between point F **283** and the resistor **274**.

Elements of the FIG. 23 Circuit:

272–Circuit Breaker	**276**–Resistor	**280**–Load
273–Diode	**277**–Auxiliary Switch	**281**–Point "D"
274–Resistor	**278**–Bi-Color LED	**282**–Point "E"
275–Resistor	**279**–Diode	**283**–Point "F"

Function:

Adding the extra diode **273** allows the circuit to be used with both AC and negative ground DC power supplies.

Item 24. Lighted position/status indicator for a mid-trip circuit breaker with built-in auxiliary switch, using bi-color LED, with the circuit breaker located between the positive side of power supply and load, for an AC (or negative ground DC) system, with current-limiting diode, lower power dissipation option.

Description:

The circuit shown in FIG. **24** is identical to that in FIG. **23**, except that a current-limiting diode **289** has been added between the resistor **288** and point E **295** (VAC Return).

Elements of the FIG. 24 Circuit:

284–Circuit Breaker	**289**–Current-Limiting Diode	**294**–Point "D"
285–Diode	**290**–Auxiliary Switch	**295**–Point "E"
286–Resistor	**291**–Bi-Color LED	**296**–Point "F"
287–Resistor	**292**–Diode	
288–Resistor	**293**–Load	

Function:

The addition of the current-limiting diode **289** allows a wider AC (or negative DC ground) supply voltage range to be tolerated.

Item 25: Lighted position/status indicator, with circuit alarm test feature (simulation of tripped auxiliary switch, circuit breakers automatically tripped), for a positive ground DC system.

Description:

The bulk of the circuit shown in FIG. **25** is identical to the FIG. **9** circuit—with one important exception. A test function has been added to the FIG. **9** circuit that allows the user to test the lighted status indicator circuit with on push-button test switch.

This test function is implemented by the addition of a momentary test switch **303** to the circuit. The momentary test switch's **303** "normally open" contact is connected to the "normally open" contact of the auxiliary switch **302**, and its "normally closed" contact is connected to the center position of the auxiliary switch (point E) **306**. Finally, the center position of the momentary test switch **303** is connected to point G **308** (+VDC).

Elements of the FIG. 25 Circuit:

297–Circuit Breaker	**301**–Bi-Color LED	**305**–Point "D"
298–Load	**302**–Auxiliary Switch	**306**–Point "E"
299–Diode	**303**–Momentary Test Switch	**307**–Point "F"
300–Resistor	**304**–Resistor	**308**–Point "G"

Function:

Under normal conditions (when the circuit breaker is in the CLOSED state), most of the current flows from point G **308** (+VDC), through the "normally closed" contact of the momentary test switch **303**, through the auxiliary switch **302**, the LED **301**, the resistor **300**, the diode **299**, the circuit breaker **297**, and then to point F **307** (negative of the DC supply). Part of the current branches off at the auxiliary switch **302** and flows to point F **307** (passing through the resistor **304**).

When the momentary test switch **303** is depressed, the current flowing from point G **308** changes direction. It will flow from point G **308** to the "normally open" contact of the

momentary test switch **303**, and then will run in two paths to point F **307**. One current path passes through the resistor **300**, the diode **299**, and the circuit breaker **297**. The other path runs through the LED **301**, and the resistor **304**, resulting in a change of current direction that causes the LED **301** to glow RED.

Since the auxiliary switch **302** and the momentary test switch **303** are in series, the opening of either switch will cause the LED **301** to turn RED. Thus, testing the circuit via the momentary test switch **303** must turn the LED **301** RED, just as the activation of the auxiliary switch **302** would. Since the diode **299** and the resistor **304** are connected to point F **307** (negative or return of the DC power supply) testing the circuit using the momentary test switch **303** will have no impact on the normal supply of power to the load **298**.

When the circuit breaker **297** has been manually turned to the OFF position, the only current flow in the circuit is from point G **308** to point F **307** (passing through the momentary test switch **303**, the auxiliary switch **302**, and the resistor **304**).

Activating the momentary test switch **303** will cause the current to pass through the LED **301**, the resistor **304**, and on to point F **307**. Current flowing through the LED **301** in this direction will cause it to turn RED, demonstrating the integrity of the circuit and the LED **301** in case of circuit breaker **297** activation.

Because the voltage polarities across the diode **299** are the same in this case (circuit breaker **297** manually set to the OFF position), no other current flow takes place. Thus the momentary test switch can be used to check the LED **301** RED condition, and associated circuit, whether the circuit breaker **297** is in the CLOSED state or is manually set to the OFF position.

When the circuit breaker **297** has been TRIPPED due to an over-current condition, the position of the auxiliary switch **302** will change, and this change in direction of the current flow through the LED **301** will cause it to glow RED.

In a TRIPPED condition, whether the momentary test switch **303** is pressed or not, the flow of current will run the same direction through the LED **301**, and it will continue to glow RED. Therefore the momentary test switch **303** could be activated anytime—regardless of the circuit breaker **297** condition—without disturbing the load **298** functionality.

While the FIG. **25** circuit has been configured to support a positive ground DC system, a similar approach could easily be used for a negative ground DC system. This circuit would require only minor modifications (including reversal of the direction of the diode **299** and bi-color LED **301**) to support a circuit breaker located between the positive side of power supply and load **298** (as in the FIG. **13** circuit). The circuit in FIG. **25** may also be built using the lower power dissipation designs previously described.

Item 26: Alarm test circuit for several lighted position/status indicator circuit breakers with auxiliary switch, for a positive ground DC system.

Description:

FIG. **26** modifies FIG. **25**, adding a diode **314** between the "normally open" positions of the auxiliary switch **317** and the momentary test switch **316**. The "normally open" position of the momentary test switch **316** (point M **319**) is also connected to several circuits similar to that shown in FIG. **25** (with an added diode), through several diodes (D1, D2, … and D*n* **315**).

Elements of the FIG. 26 Circuit:

309–Circuit Breaker	**313**–Bi-Color LED	**317**–Auxiliary Switch
310–Load	**314**–Diode	**318**–Resistor
311–Diode	**315**–Diodes D1 through D*n*	**319**–Point "M"
312–Resistor	**316**–Momentary Test Switch	

Function:

Pressing the momentary test switch **316** causes current to flow in the same direction through all of the diodes (Diodes D1 through D*n*) **315**, all of the connected circuits, and through all of the LEDs associated with those circuits.

If all of these circuits are working properly, all the associated LEDs will turn RED. Therefore, testing of several circuit breaker circuits can be accomplished using a single momentary test switch. The diode **314** and the diodes D1 though D*n* **315** serve to isolate each circuit, so that if one circuit breaker is tripped and its auxiliary switch is activated, no current will flow to the other circuits.

While the FIG. **26** circuit(s) have been configured to support a positive ground DC system, a similar approach could easily be used for a negative ground DC system. This circuit would require only minor modifications (including reversal of the direction of the diode **311** and bi-color LED **313**) to support a circuit breaker located between the positive side of power supply and load (as in the FIG. **13** circuit). The circuit in FIG. **26** may also be built using the lower power dissipation design previously described.

Item 27: One rack unit power distribution unit using mid-trip circuit breakers with lighted status/position indicator and alarm test circuit, for a positive ground DC system.

Description:

Shown in FIG. **28**, the 1 rack unit (RU) power distribution unit (PDU) receives up to two independent sources of DC power at the input, and distributes these two input power streams to several outputs. The total number of outputs that may be supported depends on the total current capability of the input power streams, and on the current requirements of the each output. The 1-RU PDU incorporates many of the technologies claimed in Items 1 through 26.

Depending upon what system in which the PDU is used, either the positive or the negative lines from the input DC power streams will pass through circuit breakers to each output. These circuit breakers may or may not be of the mid-trip variety, and may or may not include auxiliary switches. The auxiliary switch of each circuit breaker could be used either for the remote monitoring of the status of the circuit breakers, or to activate separate circuits for control or alarm purposes.

Included in the 1-RU PDU are lighted status indicator circuits, as well as circuits for remote monitoring of the PDU status, when one or more of its output circuits are interrupted by circuit breaker(s). Output connectors for the 1-RU PDU may be either individual to each output stream, or combined into one or more modules.

The positive and negative of each input line is connected to individual bus bars from which sets of cables flow power to the different outputs, passing through the circuit breakers and lighted status indicator circuits.

Depending on the system configuration, the cables that run the power to the outputs through the circuit breakers are either positive or negative. A second wire of each output (return) that does not run current through the circuit breaker is directly connected to the output. For a positive ground DC system, the negative line goes through the circuit breakers, and all loads are located between the positive side of the power supply and the circuit breakers. In the case of a negative ground DC system the positive line goes through the circuit breakers, and all loads are located between the negative side of the power supply and the circuit breakers.

FIG. **26** diagrams the lighted status indicator circuit used in this type of the system. Two sets of lighted status indicator/breaker group circuits, and a circuit for the remote monitoring of the PDU, are shown in FIG. **27**.

In this 1-RU PDU, each set of circuits drives the lighted status indicators associated with the circuit breakers in that set. Each set of circuit breakers also receives power from only

one input power stream. The two sets of circuits (each powered by the one of the two separate input power streams) are electrically isolated from each other. A single DPDT (double pole, double throw) momentary test switch **332/347** is used for testing both sets of circuits. One side of the switch is used for one set of circuits and the other side is used for the second set of circuits.

Elements of the FIG. 27 Circuit:

320–Circuit Breaker (A-side)
321–Load (A-side)
322–Diode (A-side)
323–Resistor (A-side)
324–Diode (A-side)
325–Bi-Color LED (A-side)
326–Diode (A-side)
327–Diodes D1 through D*n* (A-side)
328–Diode (A-side)
329–Relay (A-side)
330–Resistor (A-side)
331–Diodes D1 through D*n* (A-side)
332–Momentary Test Switch (A-side)
333–Auxiliary Switch (A-side)
334–Resistor (A-side)
335–Circuit Breaker (B-side)
336–Load (B-side)
337–Diode (B-side)
338–Resistor (B-side)
339–Diode (B-side)
340–Bi-Color LED (B-side)
341–Diode (B-side)
342–Diodes D1 through D*n* (B-side)
343–Diode (B-side)
344–Relay (B-side)
345–Resistor (B-side)
346–Diodes D1 through D*n* (B-side)
347–Momentary Test Switch (B-side)
348–Auxiliary Switch (B-side)
349–Resistor (B-side)
350–PDU Status Output

Elements of FIG. 28:

351–PDU, Front View
352– PDU, Rear View

Function:

Under normal operating conditions (circuit breakers are in the CLOSED/ON state), when the input power streams are applied, and there has been no over-current condition in any of the circuit breakers, the relays for the input power stream “A” **329** and for the input

power stream "B" **344** are activated, and contacts of both relays are closed. The contact closure of relay "A" **329**, in series with a similar contact closure for relay "B" **344** (used with input power stream "B"), is used for the remote monitoring of the status of the PDU though a connector **350** on the back of the unit.

Since manually setting any circuit breaker **320/335** to the OFF position does not affect the status circuit for that circuit breaker's alarm, the relay **329/344** will stay energized whether or not any circuit breaker **320/335** is set to the CLOSED/ON position, or is manually turned OFF.

When an over-current condition occurs in any of the circuit breakers **320/335**, causing it to trip, or whenever the momentary alarm test switch **332/347** is pressed, the +VDC voltage associated with that breaker **320/335** will reach the negative side of the associated relay coil through the OR-ing diodes. This will cause the relay coils to have approximately the same positive voltage at both ends. Thus the relay **329/344** will no longer be energized, and the relay contact used for the remote monitoring of the PDU will open, indicating either an over-current (TRIPPED) condition, or that an alarm test taking place.

Since the two contacts of the relays "A" and "B" **329/344** are connected to each other in series, an opening of either relay contact will cause an open loop condition in the status circuit, connected to the status connector **350** on the back of the PDU. The absence of either input power "A" or "B" will cause the relay **329/344** for that particular power side not to energize, opening loop of the status output **350**, and indicating an alarm condition. The circuit in FIG. **27** may also be built using the lower power dissipation designs previously described.

FIG. **28** shows the front panel **351** and back panel **352** of a six-output, one-RU PDU. The front panel displays the status LED associated with each of the lighted status indicator circuits, while the rear panel shows the final status output connector, as well as the input and output connectors.

Item 28: Compact circuit breaker incorporating a mid-trip switch, a lighted status indicator for the ON/OFF/TRIPPED positions, auxiliary "normally open"/"normally closed" contact points for remote monitoring of the circuit breaker system, and an alarm circuit momentary test switch, for AC or a positive or negative ground DC system.

FIG. **29** shows a compact circuit breaker that incorporates a mid-trip switch, a lighted status indicator, auxiliary "normally open"/"normally closed" contact points (**358** and **359**) for remote monitoring of the breaker, and an alarm circuit momentary test switch **355**. With appropriate changes to the internal circuitry (as shown in FIGS. **30** through **34**), this design can support AC power supplies, and/or positive or negative ground DC power supplies. Lower power dissipation versions of this circuit could also be used in compact circuit breakers. The compact circuit breaker shown in FIG. **29** could also be implemented with or without the alarm circuit and momentary test switch.

Elements of FIG. 29:

353–Circuit Breaker Handle
354–Bi-Color LED
355–Alarm Test Switch
356–Power Connection to Load (return)
357–Power Connection to +VDC Supply
358–"Normally Open" Status Contact
359–"Normally Closed" Status Contact
360–"Center" Status Contact
361–Power Connection to Line (supply)

Description:

FIG. **30** diagrams the basic compact circuit breaker circuit (for a positive ground DC system). This circuit includes: a main contact **362** that carries the current to the load, a Diode **364** with its cathode connected to the load side of the main contact **362**, a Resistor **370**, where one side is connected to the line side (in this case negative) of the main contact **362**, and the other side to a Bi-color LED **366**. It also incorporates a DPDT (dual pole, dual throw) auxiliary switch **367** that activates only when the main contact of the circuit breaker **362** has been tripped by over-current flow through the main contact, and a miniature pushbutton SPDT (single pole, double throw) momentary test switch **368**.

Elements of the FIG. 30 Circuit:

362–Circuit Breaker Main Contact
363–Load
364–Diode
365–Resistor
366–Bi-Color LED
367–Auxiliary Switch
368–Alarm Test Momentary Switch
369–Connector on back of Circuit Breaker
370–Resistor

Elements of the FIG. 31 Circuit:

371–Circuit Breaker Main Contact
372–Load
373–Diode
374–Resistor
375–Bi-Color LED
376–Auxiliary Switch
377–Alarm Test Momentary Switch
378–Connector on back of Circuit Breaker
379–Resistor

Function:

The FIG. **30** circuit is designed for use only in a circuit breaker with mid-trip capability. In such a breaker, the main contact of the circuit breaker **362** opens in trip mode, only if over-limit current is passing through the main contact.

Under normal operating condition, when the main contact **362** is closed (breaker is in the Closed/On state), current will flow from the +VDC input pin, through the "normally closed" position of the momentary test switch **368**, and through the center position of the first section of the DPDT auxiliary switch **367** (through its "normally closed" contact). Current flow will continue through the bi-color LED **366**, the resistor **365**, the diode **364**, finally reaching the main contact **362** of the negative side of the power supply. This direction of current flow passes through the forward bias green chip of the LED **366** causing it to glow Green.

When an over-current condition causes the main contact **362** to trip "open" (breaker is in the Tripped state), the DPDT auxiliary switch **367** also changes its position. In the Tripped state, current will flow through the first section of the auxiliary switch **367** (via

the "normally open" path), the LED **366** (but in the opposite direction than in the CLOSED/ON condition), the resistor **370**, and on to the negative point of the power supply. As a result, the LED **366** will turn RED, indicating a tripped condition. In this TRIPPED condition, no current will flow through the diode **364** because the main contact of the breaker is open. A second section of the DPDT auxiliary switch **367** will change the state used for remote monitoring of circuit breaker status.

When the circuit breaker is in normal operating condition (CLOSED/ON), or has been manually opened (OFF), pressing the momentary test switch **367** will cause the LED **366** to turn RED. Current flowing through the "normally open" contact of the momentary test switch **368**, to the "normally open" contact of the auxiliary switch **367**, and on to the negative side of the power supply (passing through the LED **366** and the resistor **370**), causes LED **366** to glow RED.

Since this current flow is the same whether the main contact of the circuit breaker **362** is closed or manually opened, depressing the momentary test switch **368** will test the RED alarm condition of the LED **366** for either case. In both cases, it will simulate an open line of current flow through the "normally closed" contact of the DPDT auxiliary switch **367**.

The values and power rating of the resistors selected for the circuit will depend on the desired intensity for the LED **366** (for both RED and GREEN states), and on the power levels the circuit is designed to tolerate.

While the FIG. **30** circuit has been configured to support a positive ground DC system, a similar approach could easily be used for a negative ground DC system. This circuit would require only minor modifications (including reversal of the direction of the diode **364** and LED **366**) to support a circuit breaker located between the positive side of power supply and load **363** (as in the FIG. **13** circuit). The circuit in FIG. **30** may also be built using the lower power dissipation circuits previously described.

The momentary test switch **368** may also be a DPDT (Dual Poll, Dual Throw) switch. This would provide a second set of contacts that could be used to test the integrity of the status contacts (as shown in FIG. **31**).

Item 29: Circuit diagram for the compact circuit breaker incorporating a mid-trip switch, with lighted status indicator for ON/OFF/TRIPPED positions, auxiliary "normally open"/"normally closed" contact points for remote monitoring of the circuit breaker system, and an alarm circuit momentary test switch, for positive ground DC systems, with current-limiting diodes.

Description:

The circuit diagrammed in FIG. **32** modifies the FIG. **30** circuit, adding two current-limiting diodes **384** and **389**. One diode (**384**) is located between the resistor **383** and the bi-color LED **385**; the other (**389**) is located between resistor **390** and the auxiliary switch **386**.

Elements of the FIG. 32 Circuit:

380–Circuit Breaker Main Contact
381–Load
382–Diode
383–Resistor
384–Current-Limiting Diode
385–Bi-Color LED
386–Auxiliary Switch
387–Alarm Test Momentary Switch
388–Connector on back of Circuit Breaker
389–Current-Limiting Diode
390–Resistor

Function:

The addition of the current-limiting diodes (**384** and **389**) increases the circuit's DC supply voltage limit, while not allowing the current through the LED **385** to exceed that LED's limits.

While the FIG. **32** circuit has been configured to support a positive ground DC system, as before, a similar approach could easily be used for a negative ground DC system. This circuit would require only minor modifications (including reversal of the direction of the current-limiting diodes **384** and **389** and bi-color LED **385**) to support a circuit breaker located between the positive side of power supply and load **381** (as in the FIG. **13** circuit). The circuit in FIG. **32** may also be built using the lower power dissipation designs previously described.

Item 30: Circuit diagram for the compact circuit breaker incorporating a mid-trip switch, with lighted status indicator for ON/OFF/TRIPPED positions, auxiliary "normally open"/"normally closed" contact points for remote monitoring of the circuit breaker system, and an alarm circuit momentary test switch, for AC systems or positive ground DC systems.

Description:

The circuit shown in FIG. **33** is identical to the FIG. **30** circuit, save for the addition of a diode **400** between the resistor **399** and the VAC return.

Elements of the FIG. 33 Circuit:

391–Circuit Breaker Main Contact	**396**–Auxiliary Switch
392–Load	**397**–Alarm Test Momentary Switch
393–Diode	**398**–Connector on back of Circuit Breaker
394–Resistor	**399**–Resistor
395–Bi-Color LED	**400**–Diode

Function:

Adding the extra diode **400** allows the circuit to be used with both AC and positive ground DC power supplies. As before, the FIG. **33** circuit could easily be reconfigured to support a negative ground DC system with minor modifications (including reversal of the

direction of the diodes **393/400** and bi-color LED **395**). The circuit in FIG. **33** may also be built using the lower power dissipation designs previously described.

Item 31: Circuit diagram for the compact circuit breaker incorporating a mid-trip switch, with lighted status indicator for ON/OFF/TRIPPED positions, auxiliary "normally open"/"normally closed" contact points for remote monitoring of the circuit breaker system, and an alarm circuit momentary test switch, for AC systems or positive ground DC systems, with current-limiting diodes.

Description:

The circuit shown in FIG. **34** incorporates the features of both the FIGS. **32** and **33** circuits. A diode **412** (located between the resistor **411** and the VAC return), and two current-limiting diodes **405** and **410** (**405** being located between the resistor **404** and the bi-color LED **406**; **410** being located between resistor **411** and the auxiliary switch **407**) have been added to the base circuit shown in FIG. **30**.

Elements of the FIG. 34 Circuit:

401–Circuit Breaker Main Contact
402–Load
403–Diode
404–Resistor
405–Current-Limiting Diode
406–Bi-Color LED
407–Auxiliary Switch
408–Alarm Test Momentary Switch
409–Connector on back of Circuit Breaker
410–Current-Limiting Diode
411–Resistor
412–Diode

Function:

The extra diode **412** allows the circuit to be used with both AC and positive ground DC power supplies. The two current-limiting diodes **405** and **410** increase the circuit's supply voltage limit, while not allowing the current through the LED **406** to exceed that LED's limits.

Like circuits in FIG. **30** through FIG. **33**, the FIG. **34** circuit could easily be reconfigured to support a negative ground DC system with minor modifications (including reversal of the direction of the diodes **403** and **412**, the current-limiting diodes **405** and **410**, and bi-color LED **406**). The circuit in FIG. **33** may also be built using the lower power dissipation designs previously described.

Item 32—Lighted Status Indicator for a mid-trip circuit breaker using a SPDT as a main contact and an auxiliary switch SPDT for tripped status indication, for a positive ground DC system.

Description:

In the circuit diagrammed in FIG. **35**, the circuit breaker includes two switches (**413** and **414**). The main contact **413** can be turned ON or OFF manually, and will be turned OFF automatically when the current running through the circuit breaker main contact **413** exceeds a preset value. The auxiliary switch **414** will be in the ON position except when the main contact **413** has been activated automatically by a current overload, and has tripped to the OFF position. In such a case, the auxiliary switch **414** will also be moved to the OFF position.

Elements of the FIG. 35 Circuit:

413–Main Contact	**416**–Resistor	**419**–Load
414–Auxiliary Switch	**417**–Bi-Color LED	
415–Resistor	**418**–Diode	

Function:

When the circuit breaker has been manually set to the OFF position, the auxiliary switch **414** stays in the ON position, and the supply voltage (-VDC) is completely disconnected from the circuit and no current flows through the bi-color LED **417** (the bi-color LED **414** is in the OFF state).

When the circuit breaker is manually set to the ON position, the auxiliary switch **414** remains in the ON position (and is disconnected from resistor **415** and the bi-color LED **417**), and the supply (-VDC) is connected to the diode **418** and the load **419**. In this configuration, a current flows from the positive ground, through the resistor **415**, the GREEN LED of the bi-color LED **417**, the diode **418**, the main contact **413**, and on to the supply (–VDC). Therefore when the current running through the circuit breaker main contact **418** is within the preset limit, the auxiliary switch **414** remains in the ON position, and the bi-color LED **417** glows GREEN. A second current flows through the circuit running from the positive ground, through the resistor **416**, the diode **418**, the main contact **413**, and on to the supply (–VDC).

When the current flowing through the main contact **413** exceeds the preset value, the circuit breaker will be activated and both the main contact **413** and the auxiliary switch **414** will shift to their OFF positions. In this case, the main contact **413** will disconnect the load and the diode **418** from the supply voltage (-VDC). The auxiliary switch **414** (now also tripped to its OFF position) will cause the supply voltage (-VDC) to be connected to the resistor **415** and to the bi-color LED through the main contact **413** and the auxiliary switch **414**. In this case, a current will flow from the positive ground, through the resistor **416**, the RED LED of the bi-color LED **417**, the auxiliary switch **414**, the main contact **413**, and on to the supply (-VDC). A second flow of current will run from the positive ground, through the resistor **415**, the main contact **413** and the auxiliary switch **414**, to the supply (-VDC). The amounts of both currents are limited by resistor values. Therefore when an overcurrent condition causes the circuit breaker to trip, both the main contact **413** and the auxiliary switch **414** will be activated. Only under this condition will the bi-color LED **417** glow RED.

The resistors **416** and **415** may be replaced with current-limiting diodes. Several current-limiting diodes may be used in series in order to use the FIG. **35** circuit with higher supply voltages.

Item 33—Lighted Status Indicator for a mid-trip circuit breaker using a SPDT as a main contact and an auxiliary switch SPDT for tripped status indication for a negative ground DC system.

Description:

The FIG. **36** circuit is the same as the circuit shown in FIG. **35**, except that the direction of the diode **425** and the bi-color LED **424** have been reversed, in order to allow the circuit to work in a negative ground DC system.

Elements of the FIG. 36 Circuit:

420–Main Contact	**423**–Resistor	**426**–Load
421–Auxiliary Switch	**424**–Bi-Color LED	
422–Resistor	**425**–Diode	

Function:

When the circuit breaker (main contact **420** and auxiliary switch **421**) is manually turned OFF the load **426**, and the diode **425**, are disconnected from the supply (+VDC) causing the bi-color LED **424** to remain in its OFF state.

When the circuit breaker is turned to the ON position—and the current through the circuit breaker is within the preset limits—the main contact **420** remains in the ON position and is disconnected from the resistor **422** and the bi-color LED **424**. In this state of the circuit, a current will flow through the main contact **420**, the diode **425**, the GREEN LED of the bi-color LED **424**, the resistor **422**, and on to the ground. A second current exists, flowing through the main contact **420**, the diode **425**, the resistor **423**, and on to the ground.

When the circuit breaker is activated due to an overcurrent condition, the main contact **420** and the auxiliary switch **421** will both shift to their OFF positions. In this state, the only current flowing through the circuit will be: (a) from the +VDC supply, through the main contact **420**, the auxiliary switch **421**, the RED side of the bi-color LED **424**, resistor

423, and on to the ground; and (b) from the +VDC supply through the main contact **420**, the auxiliary switch **421**, the resistor **422**, and on to the ground. Thus only the tripped condition of the breaker will cause the RED side of the bi-color LED **424** to be activated.

Item 34—Lighted Status Indicator for a mid-trip circuit breaker using a SPDT as a main contact and an auxiliary switch SPDT for tripped status indication for a positive ground DC or an AC system.

Description:

The circuit shown in FIG. **37** is identical to that shown in FIG. **35**, except for the placement of a diode **429**, between the resistor **430** and the OFF contact position of the auxiliary switch **428**.

Elements of the FIG. 37 Circuit:

427–Main Contact	**430**–Resistor	**433**–Diode
428–Auxiliary Switch	**431**–Resistor	**434**–Load
429–Diode	**432**–Bi-Color LED	

Function:

The addition of the diode **429** will cause current to flow only in a half-cycle through the circuit. Half-cycle current flow only occurs when the ground polarity is positive with respect to the –VDC supply. The circuit is only active during this half-cycle time for both RED and GREEN displays of the bi-color LED **432**.

Otherwise, the function of this circuit is identical to the circuit described under FIG. **35**.

Item 35—Lighted Status Indicator for a mid-trip circuit breaker using a SPDT as a main contact and an auxiliary switch SPDT for tripped status indication for a negative ground DC or an AC system.

Description:

The circuit diagrammed in FIG. **38** is identical to that shown in FIG. **36**, except for the placement of a diode **437**, between the resistor **438** and the OFF contact position of the auxiliary switch **436.**

Elements of the FIG. 38 Circuit:

435–Main Contact	**438**–Resistor	**441**–Diode
436–Auxiliary Switch	**439**–Resistor	**442**–Load
437–Diode	**440**–Bi-Color LED	

Function:

The addition of the diode **437** will cause current to flow only in a half-cycle through the circuit. Half-cycle current flow only occurs when the ground polarity is negative with respect to the +VDC supply. The circuit is only active during this half-cycle time for both RED and GREEN displays of the bi-color LED **440**.

Otherwise, the function of this circuit is identical to the circuit described under FIG. **36**.

Item 36—Lighted Status Indicator for a mid-trip circuit breaker using a SPST as a main contact and an auxiliary switch SPST for tripped status indication for a negative ground DC or an AC system.

Description:

The circuit diagrammed in FIG. **39** is identical to that shown in FIG. **38**, except that the main contact **443** and the auxiliary switch **444** are SPST (single pole, single throw) switches rather than SPDT (single pole, double throw) switches, whose center points are tied together and to the +VDC source

Elements of the FIG. 39 Circuit:

443–Main Contact	**446**–Resistor	**449**–Diode
444–Auxiliary Switch	**447**–Resistor	**450**–Load
445–Diode	**448**–Bi-Color LED	

Function:

When the circuit breaker is manually turned off, the load and the Diode **449** are disconnected from the +VDC supply (the auxiliary switch **444** being in the OFF state), the bi-color LED **448** will be in the OFF state, as well.

When the circuit breaker is turned to the ON position—and the current through the circuit breaker is within the preset limits—the main contact **443** will remain in the on position and be disconnected from the diode **445**, the resistor **446**, and the bi-color LED **448**. In this state, a current will flow through the main contact **443**, the diode **449**, the Green LED of the bi-color LED **448**, the resistor **446**, and on to the ground. A second current will also exist, flowing through the circuit breaker main contact **443**, the diode **449**, the resistor **447**, and on the ground.

When the circuit breaker is activated due to an overcurrent condition, the main contact **443** will shift to the OFF position, and the auxiliary switch **444** will shift to the ON (TRIPPED) position. In this state, the only currents flowing through the circuit will be:

(a) From the +VDC supply, through the main contact's **443** center contact, the auxiliary switch **444** contact, the diode **445**, the RED side of the bi-color LED **448**, the resistor **447**, and on to the ground, and

(b) From the +VDC supply, thought the main contact's **443** center contact, the auxiliary switch **444** contact, the diode **445**, the resistor **446**, and on to the ground.

Thus only the TRIPPED condition of the breaker will cause the RED side of the bi-color LED **448** to be activated.

Item 37—Lighted Status Indicator for a mid-trip circuit breaker using a SPST as a main contact and an auxiliary switch SPST for tripped status indication for a positive ground DC or an AC system.

Description:

The circuit diagrammed in FIG. **40** is similar to the circuit shown in FIG. **37**, with the following exceptions:

(1) The main contact **451** is a SPST (single pole, single throw) switch, normally placed in the OFF position (the circuit is in the OFF position), and can be turned ON or OFF manually and turned OFF automatically (TRIPPED mode).

(2) The auxiliary switch **452** is a SPST (single pole, single throw) switch, normally placed in the OFF position which will only shift to the ON position when the main circuit breaker contact **451** is tripped.

(3) The center points of the main contact **451** and the auxiliary switch **452** are connected to each other and to the –VDC.

Elements of the FIG. 40 Circuit:

451–Main Contact	**455**–Resistor	**459**–Point "B"
452–Auxiliary Switch	**456**–Bi-Color LED	**460**–Point "D"
453–Diode	**457**–Diode	
454–Resistor	**458**–Load	

Function:

When the main contact **451** is in the OFF position, the auxiliary switch **452** is also in the OFF position, and –VDC is disconnected from the diode and the load. But when the main contact **451** is set in the ON position, the –VDC supply is connected to the Load **458** and Diode **457**, and the auxiliary switch **452** remains in the OFF position and disconnected from the diode **453**, the bi-color LED **456**, and the resistor **454**.

Besides the main current flowing through the load, a current flow will run from the positive (+) ground through the resistor **454**, through the GREEN side of the bi-color LED **456**, the diode **457**, the main contact **451**, and on to the –VDC. A second current flow will run from the positive (+) ground, through the resistor **455**, the diode **457**, the main contact **451**, and on to the –VDC. In this state, the GREEN LED of the Bi-Color LED **456** will indicate that the circuit is ON and normally operational.

When an overcurrent load condition causes the main circuit breaker contact **451** to trip, the main contact **451** will open up the current flow to the load and the diode **457**. At the same time, the auxiliary switch **452** will flip to its ON state and connect –VDC to the diode **453**, the bi-color LED **456**, and the resistor **454**. In this condition of the circuit, a current flows from the positive (+) ground through the resistor **455**, the RED side of the bi-color LED **456**, the diode **453**, the auxiliary switch **452**, the center of breaker main contact **451**, and on to the –VDC. A second current path exists from the positive (+) ground, through the resistor **454**, the diode **453**, the auxiliary switch **452**, the center of the main contact **451**, and on to the –VDC supply. In this state, the RED side of the bi-color LED **456** will be ON, indicating that the breaker has tripped.

Resistors **455** and **454** may be replaced with current-limiting diodes. Also, several current-limiting diodes may be used in series to modify the FIG. **40** circuit for use with higher supply voltages. A circuit identical to the FIG. **40** circuit may be used for a negative ground DC system if the direction of the diodes (**457** and **453**) and the bi-color LED **456** are reversed.

Item 38—Lighted Status Indicator for a mid-trip circuit breaker using a SPST as a main contact and an auxiliary switch SPST (or SPDT) for tripped status indication with alarm test push button switch, for a positive ground DC or an AC system.

Description:

The circuit diagrammed in FIG. **41** is identical to that shown in FIG. **40**, except that a diode has been added between Points B **472** and D **474**, and a push button alarm test switch **464** (momentary, normally open) has been added on a line between the –VDC supply and the SPST auxiliary switch **462** (the line passing through Point C **473**).

Elements of the FIG. 41 Circuit:

461–Main Contact
462–Auxiliary Switch (SPST)
463–Auxiliary Switch (SPDT option)
464–Push-Button Alarm Test Switch
465–Diode
466–Resistor
467–Resistor
468–Bi-Color LED
469–Diode
470–Diode
471–Load
472–Point "B"
473–Point "C"
474–Point "D"

Function:

When the push button test switch **464** is not pressed, this circuit functions identically to the FIG. **40** circuit. However, when the push button test switch **464** is pressed, it bypasses the main contact **461** and the auxiliary switch **462**, causing the supply voltage to be applied to the tripped contact of the auxiliary switch **462**, thus simulating a tripped condition for the auxiliary switch **462**, regardless of the position of the main contact **461**.

This circuit allows two possible positions of the main contact **461**—Off and On. Circuit function for both positions is detailed below.

If the main contact **461** is in the Off position then a current flow will exist from the positive ground through the resistor **466**, the diode **465**, the push button test switch **464**, and on to the –VDC supply. A second current flow will run from the positive ground through the resistor **467**, the Red LED of the bi-color LED **468**, the diode **465**, the push button test switch **464**, and on to the –VDC supply. This current flow will cause the Red

side of the bi-color LED **468** to glow, indicating that the alarm circuit is working properly.

If the main contact **461** is in the ON position while the –VDC supply is powering the load, the two current flows described above exist—along with a third current path that flows from the positive ground, through the resistor **467**, the diodes **469** and **470**, the main contact **461**, and on to the –VDC supply.

The addition of the diode **470** (or a resistor in its place) will cause the voltage at point D **474** to be positive enough with respect to point C **473**, to cause the RED side of the bi-color LED **468** to turn ON and the GREEN side of the bi-color LED **468** to turn OFF (points B **472** and C **473** are at the –VDC potential). Thus the RED side of the bi-color LED **468** will indicate the proper functionality of the alarm circuitry without having any effect on the supply voltage to the Load **471**.

Notes: Diode **470** may be replaced by a Zener diode or a resistor; resistors **467** and **466** may be replaced with current-limiting diodes; and Diode **465** is used for AC applications.

The circuit in FIG. **41** will also function identically with a SPDT auxiliary switch **463** substituted for the SPST auxiliary switch **462** shown in the main circuit diagram (see also Item 39 below).

Item 39—Lighted Status Indicator for a mid-trip circuit breaker using a SPST as a main contact and an auxiliary switch (SPDT) for tripped status indication with alarm test push button switch, for a positive ground DC or an AC system.

Description:

This circuit in FIG. **42** details the SPDT (single pole, double throw) for the auxiliary switch **477** version of FIG. **41** designed for a positive ground DC (or AC) system. This

version of the circuit has the auxiliary switch **477** placed differently in the circuit and the diode **470** (of FIG. **41**) is replaced with a resistor **484**.

Elements of the FIG. 42 Circuit:

475–Point "A"	**482**–Bi-Color LED
476–Main Contact (SPST)	**483**–Resistor
477–Auxiliary Switch (SPDT)	**484**–Resistor
478–Point "C"	**485**–Diode
479–Diode	**486**–Point "B"
480–Resistor	**487**–Load
481–Point "D"	**488**–Push-Button Alarm Test Switch

Function:

This circuit works like FIG. **41** circuit, except that the FIG. **42** configuration (and not the configuration of FIG. **41**) is used when multiple circuit breakers are connected to the same push-button alarm test switch **488** (momentary, normally open).

In such a case, when the alarm test switch **488** is pressed, all alarm circuits are tested at the same time within the same system (positive or negative ground). Also in this version of the circuit, when a circuit breaker is tripped, the circuit associated with that circuit breaker will be disconnected from the test switch **488**.

Item 40—Lighted Status Indicator for a mid-trip circuit breaker using a SPDT as a main contact and an auxiliary switch (SPDT) for tripped status indication with alarm test push button switch, for a negative ground DC (or an AC) system.

Description:

This circuit in FIG. **43** is the negative ground DC version of the circuit in FIG. **42**. It is identical to the FIG. **42** circuit except that the directions of the diodes **499** and **493** and the bi-color LED **496** have been reversed.

*Elements of the FIG. **43** Circuit:*

489–Point "A"

490–Main Contact (SPST)

491–Auxiliary Switch (SPDT)

492–Point "C"

493–Diode

494–Resistor

495–Point "D"

496–Bi-Color LED

497–Resistor

498–Resistor

499–Diode

500–Point "B"

501–Load

502–Push-Button Alarm Test Switch

Function:

The FIG. **43** circuit functions identically to the circuit diagrammed in FIG. **42**, except that the direction of the diodes **499** and **493**, bi-color LED **496**, and current flow are reversed.

Item 41—Lighted Status indicator for a fuse with alarm circuit and alarm test switch, for a positive ground DC (or AC) system.

Description:

The FIG. **44** circuit is functionally identical to the FIG. **41** circuit except that a fuse **503** has replaced the main contact **461** and the auxiliary switch **462** (of FIG. **41**).

*Elements of the FIG. **44** Circuit:*

503–Fuse with Alarm Contact

504–Push-Button Alarm Test Switch

505–Diode

506–Resistor

507–Point "A"

508–Bi-Color LED

509–Resistor

510–Diode

511–Resistor

512–Point "B"

513–Load

Function:

The circuit in FIG. **44** functions identically to the circuit shown in FIG. **41**. Removal of the fuse **503** corresponds to manually turning off the power to the Load **513**. In this case, the –VDC is completely disconnected from Points A **507** and B **512**. When excessive current at the Load **513** blows the fuse **503**, Point B **512** will be disconnected from the –VDC supply, and the diode **505** will be connected to the –VDC supply through Point A **507** of the fuse **503**.

Reversing the directions of the diodes **510** and **505** and the bi-color LED **508** creates a version of this circuit for use with a negative ground DC supply.

Item 42—Compact Module (L-Module) for Display of Individual Breaker Status.

Description:

The "L-Module" **515** (detailed in FIG. **45**) is a compact, breaker-mounted module that provides a front panel visual display of the exact status of a circuit breaker equipped with an auxiliary status switch (where the status switch is only activated in the TRIPPED state of the breaker). Breaker status is indicated via an LED status indicator **519** located next to the breaker. This LED status indicator **519** and associated status circuitry are encased inside of a compact module–the L-Module **515**–attached to the connector lugs on the back of the circuit breaker **514**.

Elements of FIG. 45:

514–Breaker	**516**–Load Contact	**518**–Status/Test Port
515–L-Module	**517**–Line Contact	**519**–LED Status Indicator

Elements of FIG. 46:

520–Line and Load Contacts

521–Daisy-Chain Cable

522–Status/Test Port

523–L-Module 1

524–L-Module 2

525–L-Module n

526–Breaker 1

527–Breaker 2

528–Breaker n

529–Alarm/Status Module (A/S-Module)

530–A/S-Module Alarm Summary Out

531–A/S-Module Ground Contact

532–Alarm Test Switch

Function:

The FIG. **40** circuit diagram (shown in Item 37) shows the design of the basic L-Module circuit. FIG. **41** (shown under Item 38) diagrams the L-Module **515** with an added alarm test function. Note that just as in Item 38, resistors **467** and **466** (of FIG. 41) may be replaced with current-limiting diodes. Similarly, diode **465** (of FIG. 41) may be added for use with for AC applications, and a Zener diode or a resistor may replace diode **470** (of FIG. 41).

As shown in FIG. **46,** Multiple L-Modules (**523**, **524**, and **525**) may be connected in series, allowing a panel of breakers with L-Modules to all be tested using one common test switch **532** (in FIG. **46**) or **488** (in FIG. **42**) using the FIG. **42** circuit. That common test switch, along with an alarm status contact provision **530**, is placed in a separate module—the Alarm/Status Module **529** (in FIG. **46**) (see Items 43 and 44). Test lines and a ground path **521** for each L-Module are daisy-chained and terminated in the Alarm/Status Module **529** (in FIG. **46**). (Alarm/Status Module is hereafter abbreviated as A/S-Module.)

Item 43—Alarm/Status Module (Used in a Single Power System).

Description:

An A/S-Module for a single power system (shown in FIG. **47**) consists of a relay circuit **560** and a SPST (single pole, single throw), momentary, normally open, push-button switch **559** (the Alarm Test Switch), as well as a resistor **561**, a capacitor **562**, and a diode **563**.

The alarm test switch extends from the front of the A/S-Module. Pressing it tests all alarm circuits within the L-Modules, as well as the A/S-Module's dry contact alarm summary output. Pressing the alarm test switch will also turn all of the L-Module bi-color LEDs RED–regardless of breaker positions. Such a test does not impact normal breaker function, or in any way affect the current moving through the breaker.

A/S-Module inputs come from daisy-chained L-Module status lines that terminate at the A/S-Module (as shown in FIGS. **46** and **47**). The A/S-Module outputs alarm summary information for all connected breakers, from the contact points **564** of a SPDT relay **560** inside the A/S-Module, via a three-position connector.
An A/S-Module can be configured as to allow the alarm test switch **559** to be panel mounted, while the A/S-Module itself is located remotely. With this design only a minimum of panel space—just enough to mount the switch—is required.

FIG. **47** diagrams an A/S-Module together with the L-Modules it receives inputs from.

Elements of the FIG. 47 circuit:

533–Point "A-1"
534–Main Contact 1 (SPST)
535–Auxillary Switch 1 (SPDT)
536–Isolation Diode
537–Diode
538–Resistor
549–Isolation Diode
550–Diode
551–Resistor
552–Point "D-n"
553–Bi-Color LED
554–Resistor

539–Point "D-1"
540–Bi-Color LED
541–Resistor
542–Resistor
543–Diode
544–Point "B-1"
545–Load 1
546–Point "A-n"
547–Main Contact *n* (SPST)
548–Auxillary Switch *n* (SPDT)

555–Resistor
556–Diode
557–Point "B-n"
558–Load n
559–Alarm Test Switch
560–Relay
561–Resistor
562–Capacitor
563–Diode
564–Status Out

Function:

Input lines to the A/S module are:

(1) A supply voltage and return (ground) line,
(2) A line that connects (daisy-chained) the isolation diodes (running from **536** to **549**), of all the L-Modules being monitored, and
(3) A line that connects (daisy-chained) all the normally closed contact positions of the monitored L-Module's auxiliary switches 1 through *n* (**535** and **548**).

During the normal operation of the monitored breakers, there is no current flow through any of the L-Modules' isolation diodes (**536** and **549**), the A/S-Module relay **560** is energized through diode **563** and resistor **561**, and outputs from the A/S-Module relay contacts **564** indicate proper functioning of all breakers.

When an overload condition causes one or more of the L-Modules to report a TRIPPED condition in the breakers they monitor, a current will flow from the positive ground, through diode **563** and resistor **561**, the isolation diode(s) (**536** and/or **549**) of the L-Module(s) connected to the tripped auxiliary switch (**535** and/or **548**), to the breaker(s) main contact (**534** and/or **547**), and on to the –VDC supply. As a result, the voltage differential across the A/S-Module relay **560** drops to about 0.7 Volts (diode drop), de-

energizing that relay **560**, causing the relay status contacts **564** to report an alarm condition. This alarm contact condition also exists whenever system power is interrupted. Note that the capacitor **562** is used for an AC-powered system.

The push-button momentary switch **559** (alarm test switch) of the A/S-Module is used to test proper functioning of all L-Module LED status indicator circuits, as well as the relay circuit within the A/S-Module itself. Pressing the alarm test switch **559** will cause the connection of the –VDC supply voltage to all L-Modules via the normally closed contact of their auxiliary switches (**535** and **548**). This connection triggers current flows from the positive ground, through the RED sides of the L-Modules' bi-color LEDs (**540** or **553**), through their auxiliary switches (**535** and **548**), the A/S-Module's push-button alarm test switch **559**, and on to the –VDC supply at the A/S-Module.

Pressing the alarm test switch **559** also connects the isolation diodes (**536** and D6 **549**) within all L-Modules to the –VDC supply, causing the relay **560** to de-energize, thus simulating a TRIPPED condition within one or more of the monitored L-Modules.

Item 44—Alarm/Status Module (Used in a Dual Power System).

Description:

This version of the A/S-Module is similar to the A/S-Module used for single power systems, except that the momentary, alarm test switch **567** is a DPST (double pole, single throw) switch, and that a second relay **566** is added for the second power system. (FIG. **48** illustrates the circuit used for the Dual Power System A/S-Module.)

The relay contacts are daisy-chained together (via the Normally Open contacts—see FIG. **48**) to create one single status output for the entire system. Inputs to the A/S-Module are via two groups of lines—one group for each power system. The A/S-Module is designed so as to keep the two independent power systems completely isolated from each other. Since the normally open contacts of the two relays (**565** and **566**) are daisy-chained

together, the A/S-Module will report an alarm status when an over current condition occurs in any breaker of either of the two independent power systems. The A/S-Module will also report an alarm if either—or both—of the power systems A and B is absent.

Adding the capacitors **569** and C2 **572** (drawn in dotted lines), creates a version of the circuit for use in an AC power system.

*Elements of the FIG. **48** circuit:*

565–Relay 1 (A-Side)	**568**–Diode	**571**–Diode
566–Relay 2 (B-Side)	**569**–Capacitor	**572**–Capacitor
567–Test Switch (DPST)	**570**–Resistor	**573**–Resistor

Function:

This version of the A/S-Module is diagrammed in FIG. **48**. It functions in the same way as the Single Power System A/S-Module (FIG. **47**), except that the activation of the alarm test switch **567** will test the alarm circuits associated with the breakers in both power systems. The Dual Power System A/S-Module also provides a single alarm status output for the entire system.

Independent alarm status for each power system may also be provided using relays with DPDT (double pole, double throw) contacts. In this case, the second contact of each relay reports the status of the specific system monitored by that relay.

Item 45—Direct Status Output L-Module.

Description:

The Direct Status Output L-Module (FIG. **49**) is an L-Module which includes part (or all) of the A/S-Module circuitry. It supports independent monitoring of individual circuit breakers. This version of the L-Module incorporates alarm status contacts (**578**, **579**, and **580** on FIG. 49; **583** on FIG. **50**) which output at the back of the L-Module. The Direct

Status Output L-Module may also include an alarm test switch. This module is designed for use in a system where the status on a specific circuit breaker needs to be independently monitored and reported.

*Elements of FIG. **49**:*

574–Breaker
575–L-Module
576–Load Contact
577–Ground Contact
578–Normally Closed Contact
579–Normally Open Contact
580–Center Contact
581–Line Contact
582–LED Status Indicator

*Elements of the FIG. **50** circuit:*

583–Alarm Port
584–Relay
585–Resistor
586–Capacitor
587–Diode
588–Diode
589–Auxillary Switch
590–Alarm Test Switch
591–Main Contact
592–Diode
593–Resistor
594–Bi-Color LED
595–Resistor
596–Resistor
597–Diode
598–Load

Function:

The Direct Status L-Module circuit (FIG. **50**) works in an identical manner to an L-Module and an A/S-Module connected together as one system. Both the L-Module and A/S-Module—and a circuit combining both (FIG. **47**)—have previously been described (Items 42 & 43) in detail.

Item 46—L-module for circuit breakers with no auxiliary switch or circuit breakers with no mid-trip capability.

Description:

The circuit for this version of the L-Module (shown in FIG. **51**) is similar to the circuit for the basic L-Module (diagrammed in FIG. **40**), with a few significant differences. These include a relay contact **602** that is used in the place of the auxiliary switch of a mid-trip breaker, as well as latch **601** and current-sensing circuits **600** that energize that relay circuit **602**.

Elements of the FIG. **49** circuit:

599–Circuit Breaker Main Contact	**605**–Resistor
600–Current Sense with Delay	**606**–Bi-Color LED
601–Latch with Power-Up Reset	**607**–Resistor
602–DPDT Relay	**608**–Resistor
603–Status Out	**610**–Load
604–Isolation Diode	**611**–Diode

Function:

Under normal conditions when the circuit breaker main contact **599** is on, the DPDT (double pole, double throw) relay **602** is not powered, and its normally closed contact (connected to the A/S-Module) does not carry any power. In this state (as has been explained previously), the GREEN side of the Bi-Color LED **606** will turn ON.

When an excessive load current flow occurs, the current-sensing circuit **600** will trigger the latch circuit **601**, applying power to the relay **602**, and activating the relay contacts. The excessive current detection time of the current-sensing circuit is selected so as to be much shorter than the activation time of the circuit breakers being monitored.

When the circuit breaker main contact **599** is tripped, the RED side of the Bi-Color LED **606** will glow. A few milliseconds delay time incorporated in the current-sensing circuit

600 eliminates any chance of circuit activation in case of high initial in-rush current. When the cause of circuit breaker **599** activation is removed from the load side, the circuit breaker's **599** manual turn on causes the latch circuit **601** to reset, the relay **602** to de-energize, and the normal operation of the system to resume.

The isolation diode **604** line of the module allows it to be used in daisy chain configurations (as in the systems shown in FIGS. **47** and **48**). Using a DPDT relay also provides extra contacts that can be used as status contact out **603**, via the connectors on the back of the L-Module.

As an option, this version of the L-Module also may include a SPST (single pole, single throw) momentary push button test switch.

The circuit contained in this version of the L-Module (FIG. **51**) may also be used to monitor the status of a switch or a fuse.